Microclimate-Related Human Comfort as Aspect in Urban Planning: Indication of NBS Interventions to Increase Quality of Cycling Networks

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1 ABSTRACT

Climate change and environmental challenges affecting cities encourage them to reduce negative impacts of environmental challenges on human comfort and respond with sustainable spatial solutions such as Nature-based solutions (NBS). While spatial analyses are often limited in analysing dynamics between space–environmental characteristics and human comfort, there is a challenge to exploit new technologies (ICT) as the potential for the development of more inclusive analyses and monitoring. This paper reflects on one particular portable device for a simultaneous dynamic microclimatic data gathering, and by a protocol for microclimate street assessment evaluates microclimate-related comfort of cycling lanes in Ljubljana, Slovenia. By identifying correlations between spatial elements and microclimate conditions in different spatial settings, the study defines cycling lane sections of various levels of comfortability. The results suggest that ICT innovations for in-situ measurements can help urban analytics to gather and urban planners to interpret detailed microclimate-related information and can help to assess places according to microclimate issues such as high temperature, poor air quality, incrised humidity, but also disturbing noise levels. Collected data are interpreted within human comfort zones and can be linked with rates/levels of comfort. Thus, the paper contributes to urban planning by the provision of fine-grain localised data, with precise data spatial and temporal resolution. As the gathered data is geopositioned, it can be presented on a map enabling a linkage of environmental conditions within a spatial context.

Keywords: Urban planning, Nature-based solutions, Information and communication technologies, Human comfort, Microclimate

2 INTRODUCTION

Microclimate in urban areas is increasingly being affected by the impacts of climate change. As human comfort is directly reflected in human behavior, activity patterns, space usage [1, 2, 3], and microclimate-related human comfort become a crucial aspect in urban planning when designing solutions to address contemporary societal challenges. To improve the quality of living and mitigate the adverse effects of climate change, cities are trying to implement various innovative approaches and develop climate-change-resilient sustainable solutions. Urban planning plays a crucial role not only in climate mitigation by reducing global warming but also in designing solutions that facilitate natural processes, leading to the creation of pleasant microclimate conditions.

Nature-based solutions (NBS), a planning concept addressing various societal challenges, holds a promising potential for incorporating the aspect of microclimate-related human comfort in design solutions. Solutions based on mimic natural processes can directly address the societal challenges of cities [4]. However, to implement sustainable solutions that are as self-sustained as possible and deliver the desired environmental outcomes, it is crucial to integrate microclimate knowledge into the design process based on urban analyses of site specific conditions. Following Goličnik Marušić et al. [4], further, it is important to recognise local characteristics to identify the resources that are needed and/or available for the functioning of the NBSs so that NBSs can enhance/exploit the given sites‘ characteristics to the greatest possible.

The development of new Information and Communication Technologies (ICT) represents the potential for conducting comprehensive analyses, as well as exploring the interpretation of locally-based information of microclimate from a human perspective. Here, we specifically refer to portable ICT devices that enable the acquisition of detailed environmental data with precise spatial and temporal resolution. These devices have the potential to reveal the hidden dynamics between environmental characteristics and spatial context, which could assist urban planners in identifying areas where NBS interventions may be needed.

In this sense, this paper follows a pilot research that uses a particular ICT device for dynamic microclimate-related data gathering and, by using a protocol for microclimate street assessment, explores the microclimate-related comfort of cycling lanes in Ljubljana, Slovenia. Besides providing a few preliminary examples of microclimate assessment, the paper addresses the following research question: How can ICT devices for in-situ measurements aid urban analytics in gathering detailed microclimate-related information and assist urban planners in assessing places based on microclimate-related challenges?

Summing up, the research follows a bottom up aproach, of locally based environmental data collection, such as air temperature (°C), relative humidity (%), noise level (dBA), and particulate matter (e.g. PM 2.5 (µg/m³)). It developes the aproach to analyse cycling lane as comfortable and discomforatble areas, representing a first step towards identifying possible microclimate-related challlange. Such an analysis is recognised as having potential for prioritising and selecting spatial interventions that may be needed to achieve or improve the quality of a space. Since this research is still ongoing, this paper cover only one segment of the entire research. The quality of data plays an important role in urban planning, so the paper comments on data gathered in relation to usefulness of such data for urban planning analytics. By providing a few examples of analysed cycling lanes section it illustrates what kind of data can be gathered and demonstraits the potential of such data for defining comfortable and uncomfortable cycling lane sections as well as for identifying possible microclimate challange and/or suitable NBS for improvement.

2.1 Data Characteristics

To assess spaces in terms of human comfort and microclimate-related challenges, data characteristics must be understood within the context of urban planning. To interpret microclimate conditions from a human perspective and cycling experience, urban planners should work with fine-resolution data that reflect site-specific environmental conditions.

Considering that microclimate conditions in urban areas vary between 1 to 100 meters [5], it is crucial to address the appropriate spatial resolution of microclimate-related data. Therefore, the minimum recommended accuracy for distinguishing environmental conditions is approximately 100 meters; however, achieving an optimal level of accuracy would require data with a resolution as fine as 10 meters. Data spatial resolution also plays an important role, as cyclists occupy space at different time intervals during a day, and microclimate changes within a 24-hour period [5]. Therefore, the data should reflect the environmental variability that cyclists might experience at different time intervals throughout the day. In terms of microclimate-related human comfort, it is crucial to recognize that microclimate conditions arise from dynamic interactions between various microclimate parameters. These interconnected relationships significantly influence human comfort. Therefore, when conducting microclimate assessments focused on human comfort, it is essential that the data enable urban planners to interpret such simultaneous influences of microclimate parameters. Also, in practical terms, urban planning relies on map-based approaches. Therefore, graphically geolocated data in the form of maps becomes crucial.

2.2 Presentation of the Tool

The tool was developed by the University of Deusto in Bilbao, Spain. It serves for gathering and analyzing microclimate-related data at a user-experience level, focusing on site-specific environmental details. The tool enables the tracking of movement, making it usable for walking or cycling, and can be utilized in all publicly accessible spaces. The tool consists of two components: hardware (Figure 1 and Figure 2) and software.

The hardware comprises sensors for the simultaneous collection of environmental data, including air temperature (°C), relative humidity (%), barometric pressure (kPa), particulate matter (PM 1.0, PM 2.5, and PM 10.0 (µg/m³)), CO_2 gas, and noise level (dBA). The hardware is connected to a user interface (software) and is part of the publicly accessible platform called Bike Intelligent Centre. The platform provides feedback to the user and can be accessed at http://bizkaiabikeintelligence.deustotech.eu/en/datacentre (accessed on 10 April 2023). The platform offers a range of functions for analyzing microclimate parameters. The tool allows for the measurement of each mentioned parameter and subsequently presents the environmental data on a map. The data is displayed using different colors corresponding to each parameter. These colors are assigned based on a threshold classification system, where each color represents different levels of data values. The query function on the platform (software) enables the selection of specific dates and time intervals of interest for analysis. Within the platform, there is an underlying spatial map that includes essential information, such as land use and the occupation level of bicycle paths.

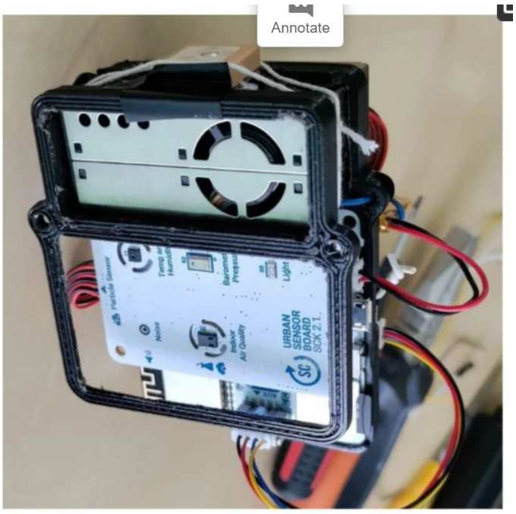

Fig. 1: Hardware consists of environmental sensors and a GPS antenna.

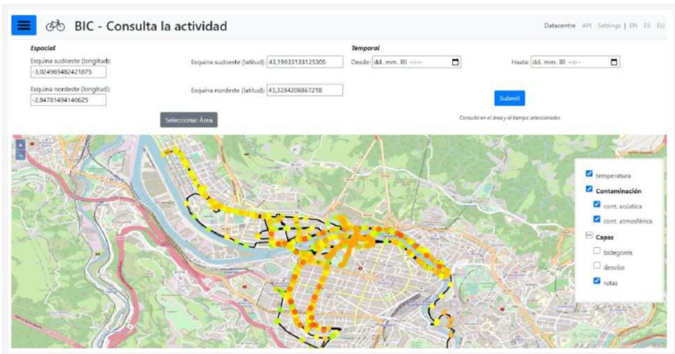

Fig. 2: User interface (software), a platform, consisting of different functions to analyse the collected data.

3 METHODOLOGY

This study adopts a case study approach, with the fieldwork conducted along the cycling lanes in Ljubljana, Slovenia. The data gathering process was carried out as an integral part of the research methodology, where the main objective was to evaluate the microclimate-related comfort of cycling lanes in the urban area.

The paper also explores the potential of ICT for assessing the level of comfort of cycling lanes regarding microclimate-related challenges and investigates the potential to identify correlations between spatial elements and microclimate conditions in different spatial settings. In that sense, we explored the potential of this ICT tool considering the following data characteristics:

- Spatial resolution,
- Temporal resolution,
- The interpretation of environmental data through human comfort parameters,
- The interpretation of environmental data within different levels of comfort zones,
- Map-making and linking environmental conditions with a spatial setting,

3.1 Field work

Data gathering was performed using the protocol for microclimate-related street assessment, consisting of several steps, which were already defined in our previous work [6]. Beside the tool, the necessary equipment for data gathering is a bicycle. Additionally, the appropriate cycling speed for data collection in relation to the frequency of the device's data capturing was set to 8 km/h to enable precise data temporal and spatial resolutions.

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3.1.1 Protocol for microclimate-related street assesment

The protocol is composed of four main steps: deffinition of the measurement area and the measurement period, selection of parameters to be measured and evaluated, definition of measurement time intervals, and analysis of collected data. They are conducted as following:

1. Definition of the Measurement Area and Measurement period

The data gathering campaign is condicted on highly occupied bicycle lanes in the urban area; in this paper applied in the case of the city of Ljubljana.

Within this first step also the duration of the measurement is defined. In our case, there were some limitations related to readiness of the device. However, as a period of observation the month of August was selected, significant for high temperatures as climate-related characteristics.

2. Selection of parameters to be measured and evaluated

To identify comfortable and uncomfortable sections and possible microclimate challenges, the microclimate-related human comfort parameters must be included in the analyses. In that sense, based on a literature review, the following microclimate parameters were selected: (a) air temperature, (b) solar radiation, (c) humidity, (d) wind velocity, and (e) air quality. In assessing human comfort, we also considered the following set of parameters: (f) level of noise, (g) human perception, and (h) other subjective parameters, such as human activity and clothing [7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17].

3. Definition of measurement time intervals

As we are specifically interested in the conditions under which people cycle for their daily commute, the data gathering was scheduled for working days (Monday to Friday) between 7:30 a.m. and 9:00 a.m., and 3:00 p.m. to 5:30 p.m. The planned campaign was set for every day in August 2022, yet data gathering was not been performed on rainy days.

4. Analysing the collected data

This is the most complex step of the protocol, comprising three levels:

(1) Data visualisation to transfer gathered data on a map to provide links between environmental conditions within a spatial context.

(2) Descriptive analysis to identify areas that offer comfort or discomfort to their users.

(3) Data interpretation to identify areas where microclimate challange is present and NBS intervention is needed.

The first step, data visualisation enables linking environmental conditions within a spatial context and must be done with the tool enabling to visualize microclimate through a medium where urban planning operates—mapping.

The second step, descriptive analyses must allow for interpreting data within the range of human comfort zones, with varying colors indicating comfortable spaces, as shown in Table 1. Currently, the descriptive analysis is based on the Bike Intelligent Centre platform, (part of the tool system), enabling to analyse data within absolute values of collected data. However to interpret the value of the difference of microclimate parameters within individual cycling sections, the data interpretation within relative values must be adressed. Another important step of discriptive analyses is related to the layering of the gatered data. First, different microclimate parameters are analysed separatedly. To identify uncomfortable areas for each microclimate parameter separately, individual gathering sessions are layerd and merged into the final maps of places with uncomfortable conditions (separating the morning and afternoon sessions for each microclimate parameter). Further step is related to the comfort rating in terms of simultaneous and integrated analysis of microclimate-related comfort parameters. Within this step the maps related to uncomfortable areas of individual parameters are merged into cumulative maps to define areas that are uncomfortable in terms of two or more parameters simultaneously.

The third step is related to data interpretation to identify areas where microclimate challange is present and NBS intervention is needed. Apart from simultaneous and integrated analysis of microclimate-related comfort parameters, this step requires a definition of a criteria referring to spatial analysis and other relevant data to consider when determining the NBS intervention.

	Temperature (°C)	Level of Noise (dBA)	Air Quality (PM 2.5)	Humidity (%)
	>40	>100	75	/
	35–40	80–100	50–75	< 15
	25–35	70–80	25–50	15–30
	15–25	60–70	20–25	30–45
	/	40–60	10–20	/
	5–15	/	/	40–60
	0–5	/	/	60–90
	<0	<40	<10	/

Table 1: Legend to interpret microclimate data in relation to human comfort values (parameter threshold classification of comfort zones). The definition of a threshold for the temperature parameter was proposed by the experts who designed the ICT tool and is based on the average temperature values for Spain [18]; noise-level thresholds are based on the environmental noise guidelines for the European Region [19]; air-quality thresholds are based on the World Health Organization's air-quality guideline values [20]; and humidity levels are based on general recommendations for indoor and outdoor humidity in European climates.

4 RESULTS

Results are presented in two parts. The first part shows some illustrative examples of data gathering, indicating the potential of such a tool for defining comfortable and uncomfortable cycling lane sections. In the second part, the results are related to the quality of data, covering aspects of spatial and temporal resolution, data characteristics related to interpretation within human comfort zones, and the ability to use map-making for identifying and interpreting the correlations between space and environmental conditions.

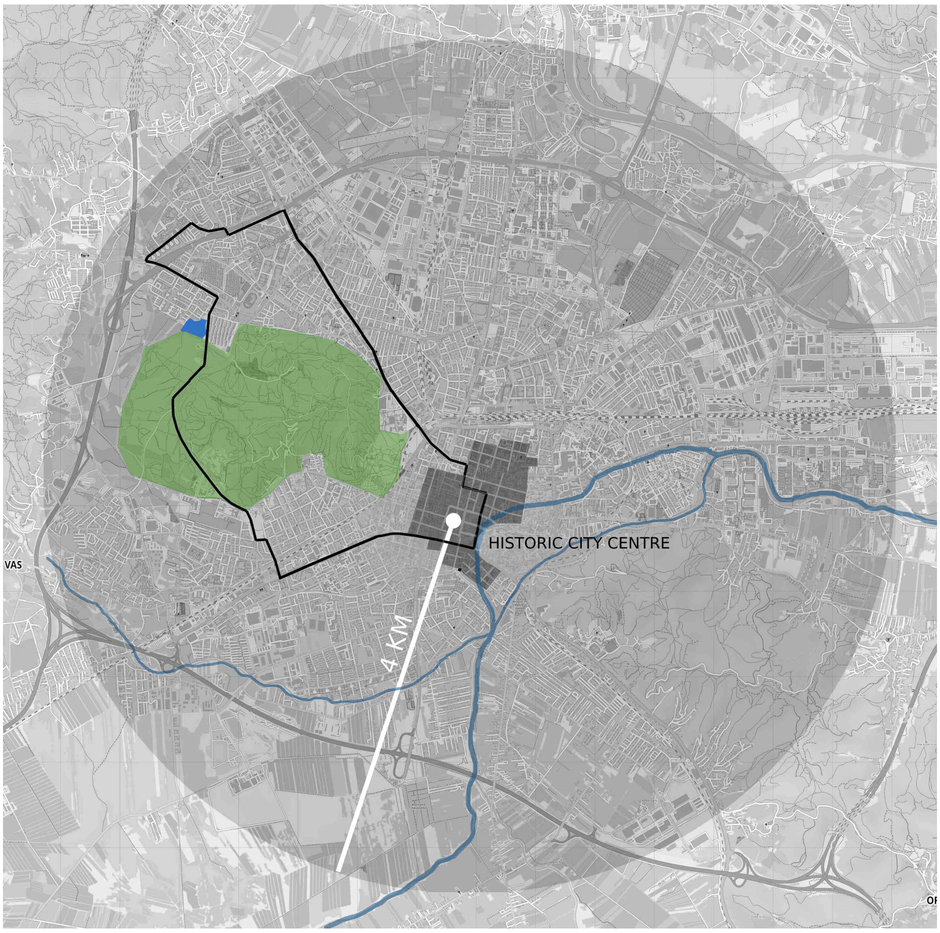

Fig. 3. Data gathering routh.

4.1 The practical performance of data gathering and illustrative examples of identifying comfortable and uncomfortable sections

Data gathering was performed almost every day in August 2022. The pre-planned route (12.5 km) led through different parts of the city, covering a variety of urban structures, including a densely built-up historic

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urban area, a densely built-up urban area, and a relatively compact urban pattern with areas of low density. According to the land-use plan, the cycling paths most often crossed areas of central activity, residential areas with accompanied activities, areas of green spaces, and forest areas. Natural morphological features were related to flat terrain, open spaces, forests, clusters of trees, water areas, and artificial non-agricultural green areas, such as urban tree lines and small-sized green surfaces.

4.1.1 Illustrative examples of data gathering, and the potential of such a tool for defining comfortable and uncomfortable cycling lane sections.

This subchapter illustrates which microclimate-related parameters can be interpreted and how such microclimate-related human comfort related data can be used within urban planning analytics.

The illustrative example of data gathering was performed in Ljubljana on Friday, August 5, 2022, between 16:06 and 16:18. Cycling Lane section led through different spatial setting, characterised by densely built-up urban tissue and densely built-up historic urban tissue. The most common natural morphological features are related to flat terrain, urban tree lines, small-sized green surfaces and also a river.

The device enabled the collection of the following parameters: air temperature, relative humidity, noise level, and particulate matter (PM 2.5), which represents the potential of identifying possible microclimate challenges in urban areas. The inclusion of these parameters is sufficient to understand the environmental conditions from an objective–numerical standpoint, which address only the physical conditions.

The gathered data is presented trough a software of the tool, a map-based platform. The routh of data gathering is represented by a track of movement, where the microclimate values are graphically represented with dots of different colors. These colors are assigned based on a threshold classification system, where each color represents different levels of data values, indicating the level of comfort (see Table 1). Such data interpretation enables to differentiate sub-areas regarding the level of comfort.

For example, the temperature parameter on the following cycling lane section (Figure 4) is mostly represented with red colour, indicating uncomfortable conditions, varying between 35.1°C and 37.2°C. Yet, cycling lane subsection following through a historic part, near the city river, the temperature values are represented with orange colours, indicating still uncomfortable conditions, yet with a lower temperature value (varying between 34.7°C - 35°C). In terms of data precision, the data enables to interpret variable microclimate conditions every 10m, enabling to identify changeable microclimate conditions on a pedestrian level. The data related to temperature indicate that every 10 meters temperature can changes between 0.1 °C and 0.8°C. Continuing with the humidity parameter, conditions are represented with yellow colour. Such colour representation is indicating comfortable conditions, varying from 35.6% and 40.2%. Every 10 meters, the humidity value can change between 1% and 1.4 %.

The level of noise is represented with three different colours, indicating subsections are different in terms of comfort level. Green colour is indicating comfortable conditions, varying between 40–60 dBA, yellow colour is indicating uncomfortable conditions, varying between 60–70 dBA and orange colour is indicating uncomfortable conditions between 70–80 dBA. Every 10 meters, the level of noise can change for 0.1 dBA and 16 dBA.

Air quality values are comfortable during the whole section (green colour), where conditions are varying between 9–17 µg/m³. Every 10 meters values differ from 1 – 8 µg/m³.

4.2 The tool's potential for urban analysis of assessing human comfort related to microclimate challenges

The findings indicate that the data's spatial resolution is accurate in capturing the changeable environmental conditions that cyclists may encounter within a few meters. While cycling at an average speed of 8 km/h, measurements were recorded by the device at 5-second intervals, resulting in data collection approximately every 10 meters. Taking into account that environmental conditions can vary between 10 and 100 meters [5], the utilization of the ICT tool enables the generation of sufficiently detailed data. Moving on to the temporal resolution, the tool facilitated data collection at any given time period throughout the day. Given that microclimate conditions change within a 24-hour cycle [5], and assuming that a commuter cyclist travels a minimum of two times per day, the results indicate that the 5-second resolution could help identify the environmental conditions experienced by cyclists during their commute. With the tool, we achieved the capability to collect a comprehensive set of human comfort parameters. The data obtained were then visualized across various human comfort zones, providing valuable insights into the comfort levels of a given space.

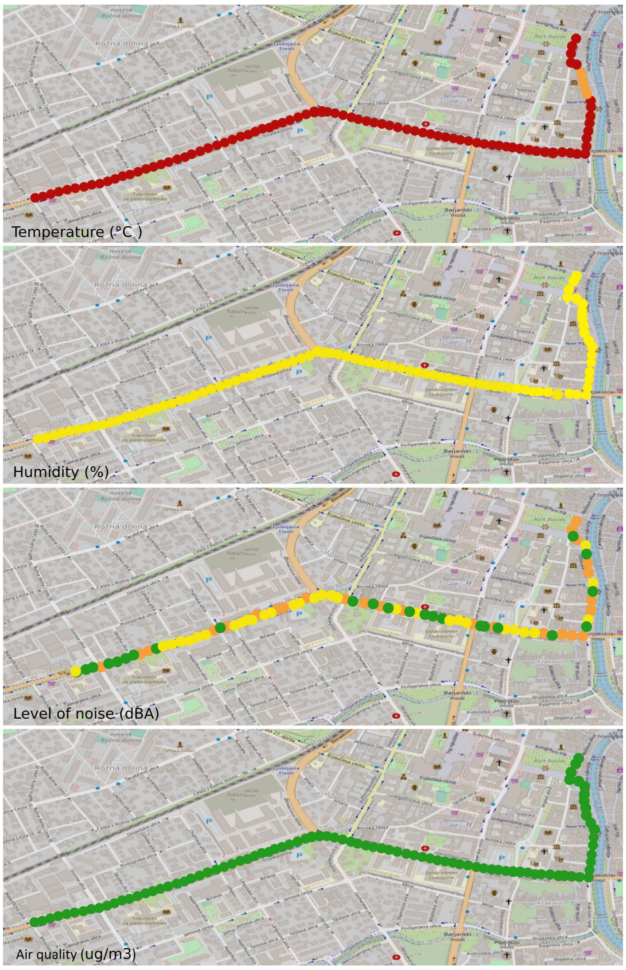

Fig. 4. The practical performance of data gathering and illustrative example of identifying comfortable and uncomfortable sections to demonstrate the potential for identifying possible microclimate challenge.

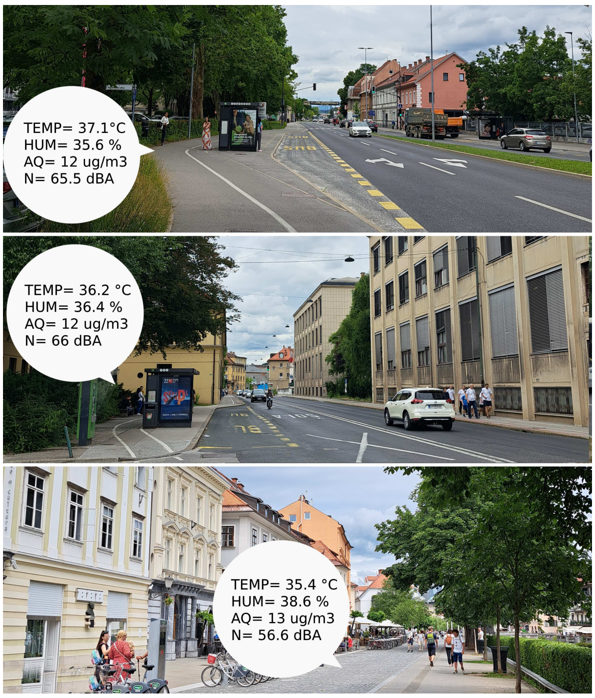

Fig. 5. Illustrative example of data gathering in real places demonstrating detailed microclimate-related information for identifying variable microclimate conditions at a pedestrian level.

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The implications of these findings are seen within urban analyses of assessing spaces in terms of microclimate-related human comfort and for identifying microclimate challenges, including high temperature, air quality, humidity, and noise level. Furthermore, in terms of its map-making capabilities, which facilitate the correlation of environmental conditions with specific spatial settings, the results indicate that the platform offers a user-friendly and visually intuitive approach to conducting environmental assessment analyses.

The findings demonstrate the potential of such data in conducting urban analyses. This valuable information can be utilized to identify and allocate necessary spatial interventions or to monitor existing sustainable solutions, ensuring their long-term environmental benefits.

5 DISCUSSION AND CONCLUSION

This paper is based on the premise that considering the microclimate in the design process of sustainable solutions can lead to improvements in environmental quality, affecting environmental conditions and supporting human comfort. However, conventional urban analyses might prove inadequate in thoroughly examining the connections among microclimate conditions, environmental characteristics, and human comfort. In that sense, the paper explores the potential of one ICT tool for assessing human comfort in a case study of cycling lanes in Ljubljana, Slovenia. Based on a microclimate-related street assessment and simultaneous dynamic environmental data gathering, the paper defines sections that are comfortable and uncomfortable, representing a first step towards identifying possible microclimate challenges.

The results suggest that ICT innovations, for in-situ measurements, can help urban analytics gather and urban planners interpret detailed microclimate-related information and assess places according to microclimate challenges. The ICT tool enabled the production of data with characteristics that support better consideration of microclimatology in urban planning. The collected data have precise temporal and spatial resolutions, enabling the identification of variable microclimate conditions within a few meters, every five seconds. In terms of data characteristics related to comfort, the results indicate that the data can be interpreted through the main microclimate parameters: air temperature, relative humidity, particulate matter (PM 1.0, 2.5, and 10.0 µg/m³), noise level and additional ones; barometric pressure (kPa), and CO_2 gas, thereby assessing the comfort of the space. The findings also suggest that the data are presented through a map-based visual representation of spatial assessment, a linkage of environmental conditions within a spatial context.

Such innovative tools for analysing site-specific environmental characteristics represent a potential within urban planning of NBS, where the data's potential is seen in urban analyses, prioritizing, and selecting spatial interventions to achieve or improve the microclimate-related human comfort of a space.

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7 REFERENCES

1. Gehl, J. Life between Buildings, 6th ed.; Island Press: Washington, DC, USA, 2011. [Google Scholar]
2. Lin, T. Thermal perception, adaptation and attendance in a public square in hot and humid regions. Build. Environ. 2009, 44, 2017–2026. [Google Scholar] [CrossRef]

3. Thorsson, S.; Lindqvist, M.; Lindqvist, S. Thermal bioclimatic conditions and patterns of behaviour in an urban park in Göteborg, Sweden. Int. J. Biometeorol. 2004, 48, 149–156. [Google Scholar] [CrossRef] [PubMed]
4. Goličnik Marušić, B.; Dremel, M.; Ravnikar, Ž. A frame of understanding to better link nature-based solutions and urban planning. Environ. Sci. Policy 2023, 146, 47–56. [Google Scholar] [CrossRef]
5. Barry, R.G. A framework for climatological research with particular reference to scale concepts. Trans. Inst. Br. Geogr. 1970, 49, 61. [Google Scholar] [CrossRef]
6. Ravnikar, Ž.; Bahillo, A.; Goličnik Marušić, B. A Protocol for Microclimate-Related Street Assessment and the Potential of Detailed Environmental Data for Better Consideration of Microclimatology in Urban Planning. Sustainability 2023, 15, 8236. https://doi.org/10.3390/su15108236
7. Frontczak, M.; Wargocki, P. Literature survey on how different factors influence human comfort in indoor environments. Build. Environ. 2011, 46, 922–937. [Google Scholar] [CrossRef]
8. Ekici, C. A review of thermal comfort and method of using Fanger's PMV equation. In Proceedings of the 5th International Symposium on Measurement, Analysis and Modelling of Human Functions, ISHF 2013, Vancouver, BC, Canada, 27–29 June 2013; pp. 61–64. [Google Scholar]
9. Elnabawi, M.H.; Hamza, N. Behavioural perspectives of outdoor thermal comfort in urban areas: A critical review. Atmosphere 2020, 11, 51. [Google Scholar] [CrossRef]
10. Lam, C.K.C.; Lau, K.K.L. Effect of long-term acclimatization on summer thermal comfort in outdoor spaces: A comparative study between Melbourne and Hong Kong. Undefined 2018, 62, 1311–1324. [Google Scholar] [CrossRef]
11. Mamani, T.; Herrera, R.F.; Rivera, M.-L.; Atencio, E. Variables That Affect Thermal Comfort and Its Measuring Instruments: A Systematic Review. Sustainability 2022, 14, 1773. [Google Scholar] [CrossRef]
12. Shooshtarian, S.; Rajagopalan, P.; Sagoo, A. A comprehensive review of thermal adaptive strategies in outdoor spaces. Sustain. Cities Soc. 2018, 41, 647–665. [Google Scholar] [CrossRef]
13. Stathopoulos, T.; Wu, H.; Zacharias, J. Outdoor human comfort in an urban climate. Build. Environ. 2004, 39, 297–305. [Google Scholar] [CrossRef]
14. Boduch, M.; Fincher, W. Standards of Human Comfort, Relative and Absolute. 2009. Available online: https://repositories.lib.utexas.edu/handle/2152/13980 (accessed on 10 April 2023).
15. Song, Y.; Mao, F.; Liu, Q. Human comfort in indoor environment: A review on assessment criteria, data collection and data analysis methods. IEEE Access 2019, 7, 119774–119786. [Google Scholar] [CrossRef]
16. Morris, K.I.; Chan, A.; Morris, K.J.K.; Ooi, M.C.G.; Oozeer, M.Y.; Abakr, Y.A.; Nadzir, M.S.M.; Mohammed, I.Y.; Al-Qrimli, H.F. Impact of urbanization level on the interactions of urban area, the urban climate, and human thermal comfort. Appl. Geogr. 2017, 79, 50–72. [Google Scholar] [CrossRef]
17. Tong, S.; Wong, N.H.; Tan, C.L.; Jusuf, S.K.; Ignatius, M.; Tan, E. Impact of urban morphology on microclimate and thermal comfort in northern China. Sol. Energy 2017, 155, 212–223. [Google Scholar] [CrossRef]
18. The State Meteorological Agency, Spain (AEMET) (n.d), Maximum and Minimum Temperatures. AEMET. Available online: http://www.aemet.es/en/eltiempo/prediccion/temperaturas?dia=&zona=penyb&img=maxima (accessed on 9 November 2021).
19. World Health Organisation (WHO). Environmental Noise Guidelines for the European Region; WHO: Geneva, Switzerland, 2018; Available online: https://www.who.int/europe/publications/i/item/9789289053563 (accessed on 10 April 2022).
20. World Health Organisation (WHO). WHO Global Air Quality Guidelines; WHO: Geneva, Switzerland, 2018. [Google Scholar]